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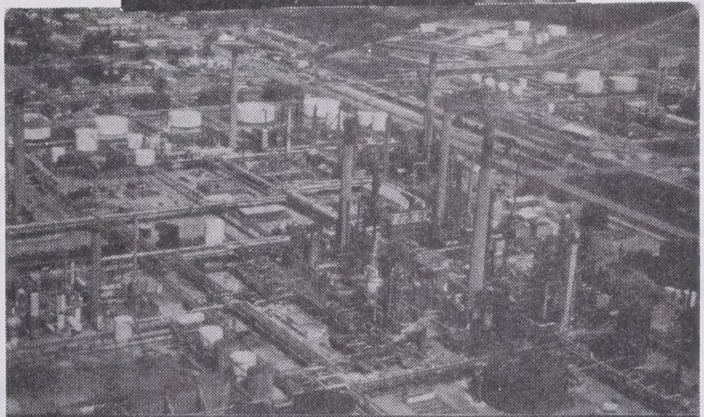
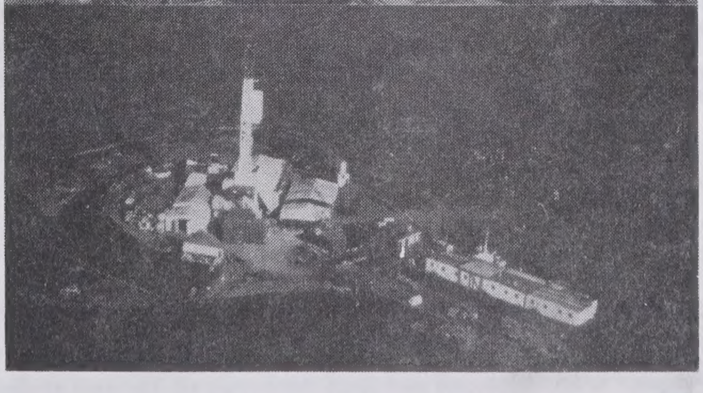
ALBERTA CHEMICAL INDUSTRIES





1979 *Preliminary Edition*

ALCHEM

ALCHEM MATERIALS

ALCHEM 10

Unit A: Elements and the Periodic Table
Unit B: Compounds and Nomenclature
Unit C: Chemical Reactions
Unit D: The Mole
Unit E: Gravimetric Stoichiometry

ALCHEM 20

Unit F: Review of ALCHEM 10
Unit G: Chemical Bonding
Unit H: Organic Chemistry
Unit I: Solutions

ALCHEM 30

Unit K: Review of ALCHEM 10 & 20
Unit L: Energy
Unit M: Electrochemistry
Unit N: Acids and Bases

ALCHEM Electives (Available separately) (level)

Unit J: Analytical Chemistry (20, 30)
Unit O: Foods and Their Analogs (30, 20)
Unit - The Athabasca Tar Sands (30, 20)
Unit P: Ethylene and its Derivatives (30)
Unit S: Alberta Chemical Industries (10)
Unit T: Metallurgy and Corrosion (30)
Unit U: Nuclear Chemistry (30, 20)

Other ALCHEM Materials

1. ALCHEM 10 Teachers' Guide
2. ALCHEM 20 Teachers' Guide
3. ALCHEM 30 Teachers' Guide
4. ALCHEM Electives Teachers' Guide
5. ALCHEM periodic table (student)
6. ALCHEM 30 data sheet (student)
7. ALCHEM 10 Test Item Bank
8. ALCHEM 20 Test Item Bank
9. ALCHEM 30 Test Item Bank
10. ALCHEM periodic table (wall chart) - Side 1
11. ALCHEM periodic table (wall chart) - Side 2
12. ALCHEM 30 data sheet (wall chart) - Side 1
13. ALCHEM 30 data sheet (wall chart) - Side 2
14. Athabasca Tar Sands wall chart
15. ALCHEM mole posters
16. ALCHEM illustrated, biography wall charts

MARVIN DAH MOLE WAS HERE
6.02×10²³

"MARVIN" The ALCHEM Mole

Dear Teacher:

If you have any suggestions or constructive criticism, please send your comments to the Authors at J.M. LeBel Enterprises, 10372 - 60 Ave. Edmonton, Alberta, T6H 1G9.

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Metric Commission Canada has granted use of the National Symbol for Metric Conversion.

TABLE OF CONTENTS
ALBERTA CHEMICAL INDUSTRIES
(Pilot Edition)

Introduction

Introduction **S1** Some Chemicals Manufactured in Alberta **S2**

Sherritt Gordon

Production of Ammonia **S4** A Fertilizer and Nickel Rifining Flowchart **S5** Leaching of Nickel ore Concentrate **S6**

Fertilizers

Introduction, History, Fertilizer Rating and Blended Fertilizers **S7** Alberta Fertilizer Plants **S9** The Two Faces of Nitrogen **S10** Fertilizers Exercise **S11** Problems Associated with Fertilizers **S13**

Other Alberta Chemical Industries

Steel Brothers Canada Ltd. (Lime Plant) **S14** Canadian Liquid Air **S15** Thio-Pet Chemicals Ltd. (Carbon Disulfide and Hydrogen Sulfide Plant) **S18** Alberta Gas Chemicals (Methanol Plant) **S19** Alberta Sulphate (Sodium Sulfate Decahydrate Plant) **S20** Mountain Minerals (Barium Sulfate Plate) **S20**

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ALBERTA CHEMICAL INDUSTRIES
OBJECTIVES

Having completed this unit the student should be able to:

1. State the names and locations of several chemical plants in Alberta
2. Give practical reasons why chemical plants are located in a particular location
3. Write the chemical equations for the chemical reactions which occur during a chemical process
4. State some uses of the chemicals produced in Alberta
5. Name the producing company for chemicals produced in Alberta.
6. Describe distillation and fractional distillation
7. Read a flow chart and extract information from it
8. Name the three essential elements to plant growth which are provided by most fertilizers
9. Define a blended fertilizer and read the fertilizer rating from the label
10. Write formulas for some common fertilizer compounds
11. State the solvent used for acetylene
12. State some of the physical processes which occur in chemical processing plants
13. Discuss two problems associated with fertilizer usage

15. State the solvent used for acetylene

Steel Brothers Canada Exshaw Lime Plant

ALBERTA CHEMICAL INDUSTRIES

INTRODUCTION

Alberta's economy, over most of her history, has been based on agriculture. Alberta developed as an *agrarian* society and by 1935 was still over 50% dependent on agricultural production. Today 18% of total production is due to agriculture and other supportive industries have developed. One of these is *Alberta's chemical industry,* which started out with the manufacture of fertilizers for agriculture. Fertilizer plants are found in Alberta due to the presence of a market on the prairies and due to the presence of natural gas, which can be used to produce ammonia, from which most fertilizers derive.

Thus agriculture provided the need and natural gas, one of the raw materials for the begining of a chemical fertilizer industry in Alberta.

The chemical industry has developed further because of petroleum and natural gas. Ammonia can be used in nickel refining and explosives production. Ethane, from natural gas, is used to make ethylene and all its by products. Butane, propane and other parts of natural gas are used to make a host of chemicals.

Alberta is underlain with huge salt deposits. From these has developed a chemical industry using salt (sodium chloride) to produce chlorine, hydrogen and sodium hydroxide. Other salts are also mined from deposits on the prairies. Other chemicals are mined from mountain rock formations.

In *Unit S Alberta Chemical Industries* those companies which produce chemicals in Alberta will be highlighted. The intent is to :

1. discuss the main chemical reactions which take place in each chemical manufacturing plant and some of the more important physical processes
2. learn the sources of raw materials with reasons for the plant being in the given location
3. study the relationships between various chemical industries located in the province
4. discuss the use of chemicals for fertilization
5. practise the naming of compounds, writing of formulas, balancing of equations and the solving of mathematical problems learned in ALCHEM 10.

The companies highlighted in this unit will be:

Sherritt Gordon Mines Ltd.
Western Co-operative Fertilizers Ltd.
Cominco Ltd.
Esso Chemical Canada - Division of Imperial Oil Enterprises Ltd.
Canadian Fertilizers Ltd.
Canadian Liquid Air Ltd.
Canadian Industries Ltd.
Steel Brothers Canada Ltd.
Alberta Gas Chemicals
Thio-Pet Chemicals Ltd.
Mountain Minerals Ltd.
Alberta Sulphate Ltd.

SOME CHEMICALS MANUFACTURED IN ALBERTA

The following exercise was compiled using the government publication Canadian Chemical Register(1975). Provide either the chemical name or formula as required. Classify the chemical as either an ionic(*i*) or molecular(*m*) substance or as an acid(*a*). Write subscripts beside every chemical formulas to indicate whether the substance is a solid(s), liquid(*l*) or gas(g).

	i, m or a	Chemical Formula	Company and Location	Name
e.g.	*i*	$Na_2SO_4(s)$	Alberta Sulfate	sodium sulfate
1.			Horseshoe Lake	sodium sulfate decahydrate
2.		_____AlO_3^{3-}	Alchem Ltd., Edmonton	sodium aluminate
3.			over 30 sulfur extracting gas plants	sulfur
4.		$CaCl_2$	Allied Chemical, Brooks	
5.			Baroid of Canada, Onoway	barium sulfate
6.		NaOCl	Bristol-Myers, Edmonton	
7.		NH_4NO_3	Canadian Industries Ltd. Calgary	
8.				nitric acid
9.		SO_3		
10.		CO_2		
11.			Canadian Liquid Air Calgary and Edmonton	hydrogen
12.				nitrogen
13.				oxygen
14.			Canadian Salt Co., Lindberg	sodium chloride
15.		$CH_3COOH_{(aq)}$	Celanese Canada, Edmonton	
16.			Cominco Ltd., Calgary and Esso Chemical, Redwater	ammonia
17.				ammonium nitrate
18.		$HNO_3(aq)$		
19.			Cominco Ltd., Calgary	carbon dioxide
20.		N_2		
21.			Dow Chemical Fort Saskatchewan	chlorine
22.				hydrochloric acid
23.		H_2		
24.		NaCl		
25.				sodium hydroxide
26.			Esso Chemical Redwater	phosphoric acid
27.		S_8		
28.		$H_2SO_4(aq)$		

ALBERTA INORGANIC CHEMICAL INDUSTRIES
SOME CHEMICALS MANUFACTURED IN ALBERTA

	i, m or a	Chemical Formula	Company and Location	Name
29.		$(NH_4)_2SO_4$	Esso Chemical, Redwater and Sherritt Gordon Fort Saskatchewan	
30.				ammonium phosphate
31.		$(NH_4)_2HPO_4$		
32.				ammonium dihydrogen phosphate
33.		NH_3	Sherritt Gordon Fort Saskatchewan	
34.		CO_2		
35.				cobalt
36.			Inland Chemicals Fort Saskatchewan	aluminum sulfate
37.				sulfuric acid
38.			Liquid Carbonic Fort Saskatchewan	carbon dioxide
39.			Steel Brothers Exshaw	calcium hydroxide
40.		CaO		
41.		$CS_2(l)$	Thio-Pet Chemicals Fort Saskatchewan	
42.				hydrogen sulfide
43.			Two Hills Chemical Co. Two Hills	calcium chloride
44.		Cl_2		
45.		NaOH		
46.				sodium hypochlorite
47.			Union Carbide Edmonton	argon
48.				nitrogen
49.		N_2O		
50.		O_2		
51.			Western Co-operative Fertilizers, Calgary and Medicine Hat	ammonia
52.				ammonium nitrate
53.		$(NH_4)_3PO_4$		
54.				ammonium sulfate
55.		$NH_4H_2PO_4$		
56.				ammonium hydrogen phosphate
57.				nitric acid
58.		$H_3PO_4(aq)$		
59.				sulfuric acid
60.		$HCl_{(aq)}$	Uniroyal Chemical Clover Bar	

SHERRITT GORDON

The Sherritt Gordon complex at Fort Saskatchewan was originally built to refine nickel. However, Sherritt's nickel refining process used a considerable quantity of Sherritt produced ammonia, which is made from natural gas. To make full use of this ammonia Sherritt Gordon also now makes fertilizers.

Production of Ammonia

Sherritt Gordon uses Alberta's natural gas (85-90% methane) to produce ammonia.

1. Using the three word equations in the chart on Page S5 under *Ammonia Production*, write complete balanced chemical equations for the process to produce ammonia.

2. Ammonia is produced in great quantities (about 400 t/d) (1 t = 1000 kg exactly). How many moles of hydrogen gas would be required?

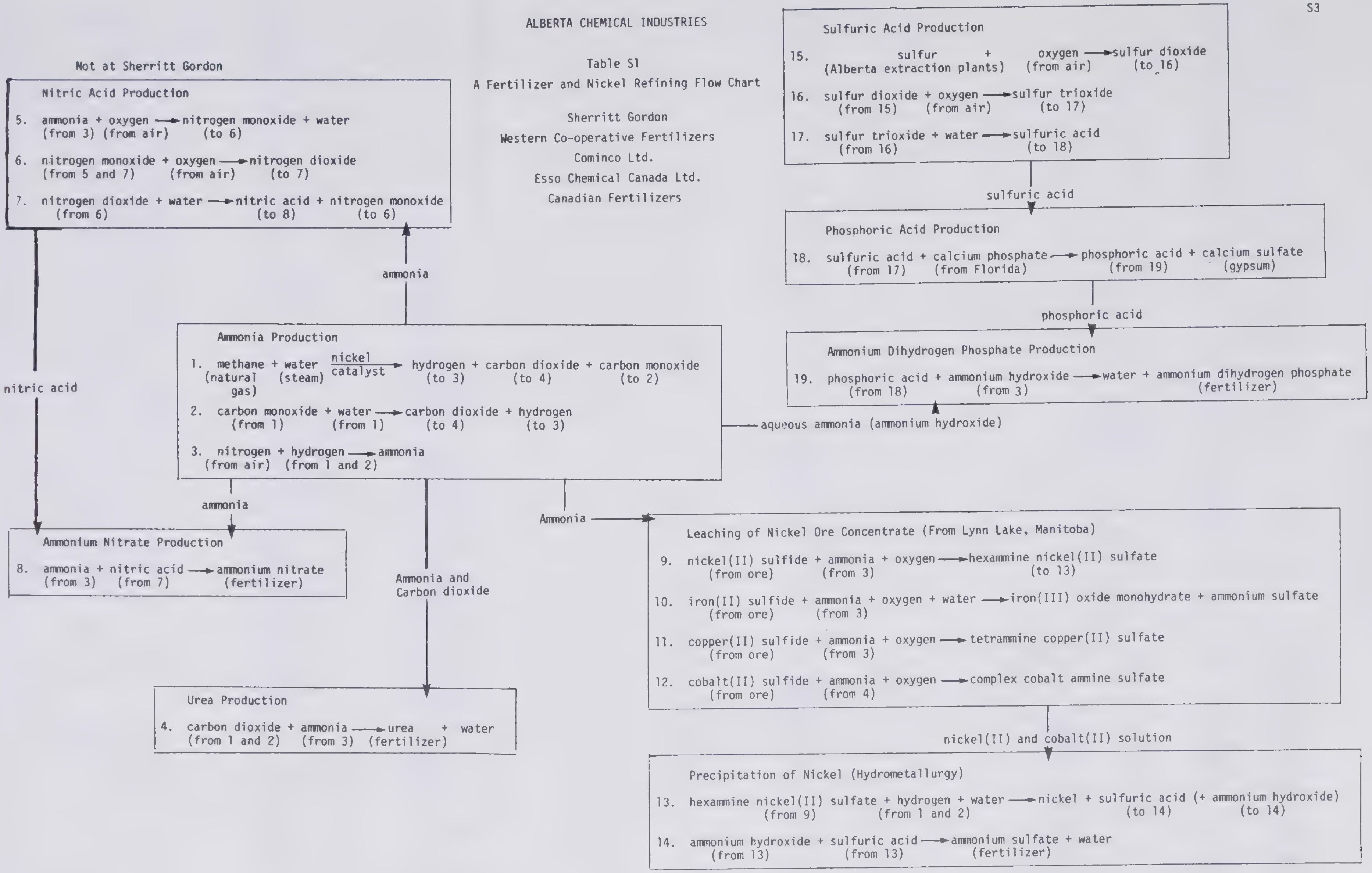
The industrial process represented by the third reaction is called the Haber process. It was formulated by Fritz Haber just before World War I. The ammonia produced by this process is used by Sherritt Gordon in several reactions.

ALBERTA CHEMICAL INDUSTRIES

Table S1

A Fertilizer and Nickel Refining Flow Chart

Sherritt Gordon
Western Co-operative Fertilizers
Cominco Ltd.
Esso Chemical Canada Ltd.
Canadian Fertilizers


ammonia
nitric acid
ammonia
Ammonia and Carbon dioxide
Ammonia
aqueous ammonia (ammonium hydroxide)
sulfuric acid
phosphoric acid
nickel(II) and cobalt(II) solution

Not at Sherritt Gordon

Nitric Acid Production

5. ammonia + oxygen → nitrogen monoxide + water
(from 3) (from air) (to 6)

6. nitrogen monoxide + oxygen → nitrogen dioxide
(from 5 and 7) (from air) (to 7)

7. nitrogen dioxide + water → nitric acid + nitrogen monoxide
(from 6) (to 8) (to 6)

Ammonia Production

1. methane + water $\xrightarrow[\text{catalyst}]{\text{nickel}}$ hydrogen + carbon dioxide + carbon monoxide
(natural gas) (steam) (to 3) (to 4) (to 2)

2. carbon monoxide + water → carbon dioxide + hydrogen
(from 1) (from 1) (to 4) (to 3)

3. nitrogen + hydrogen → ammonia
(from air) (from 1 and 2)

Ammonium Nitrate Production

8. ammonia + nitric acid → ammonium nitrate
(from 3) (from 7) (fertilizer)

Urea Production

4. carbon dioxide + ammonia → urea + water
(from 1 and 2) (from 3) (fertilizer)

Sulfuric Acid Production

15. sulfur + oxygen → sulfur dioxide
(Alberta extraction plants) (from air) (to 16)

16. sulfur dioxide + oxygen → sulfur trioxide
(from 15) (from air) (to 17)

17. sulfur trioxide + water → sulfuric acid
(from 16) (to 18)

Phosphoric Acid Production

18. sulfuric acid + calcium phosphate → phosphoric acid + calcium sulfate
(from 17) (from Florida) (from 19) (gypsum)

Ammonium Dihydrogen Phosphate Production

19. phosphoric acid + ammonium hydroxide → water + ammonium dihydrogen phosphate
(from 18) (from 3) (fertilizer)

Leaching of Nickel Ore Concentrate (From Lynn Lake, Manitoba)

9. nickel(II) sulfide + ammonia + oxygen → hexammine nickel(II) sulfate
(from ore) (from 3) (to 13)

10. iron(II) sulfide + ammonia + oxygen + water → iron(III) oxide monohydrate + ammonium sulfate
(from ore) (from 3)

11. copper(II) sulfide + ammonia + oxygen → tetrammine copper(II) sulfate
(from ore) (from 3)

12. cobalt(II) sulfide + ammonia + oxygen → complex cobalt ammine sulfate
(from ore) (from 4)

Precipitation of Nickel (Hydrometallurgy)

13. hexammine nickel(II) sulfate + hydrogen + water → nickel + sulfuric acid (+ ammonium hydroxide)
(from 9) (from 1 and 2) (to 14) (to 14)

14. ammonium hydroxide + sulfuric acid → ammonium sulfate + water
(from 13) (from 13) (fertilizer)

Leaching of Nickel Ore Concentrate

Sherritt Gordon mines nickel ore at Lynn Lake, Manitoba. This nickel ore is concentrated and shipped by rail to Edmonton. The ore contains the sulfides of several metals (nickel, copper, iron and traces of cobalt).

The process for refining nickel that Sherritt Gordon uses, called hydrometallurgy, is unique in that it uses low temperatures, low pressure and a precipitation reaction with hydrogen gas.

1. Turn to the chart on Page S5. (Equation 9). Write balanced chemical equations for the leaching of nickel sulfides.
   (Hexammine nickel(II) sulfate is $Ni(NH_3)_6SO_4$.)

2. 1750 t/d of hexammine nickel(II) sulfide is produced. How many moles of ammonia would be required?

The iron(III) oxide monohydrate is left in the tailings pond and the tetrammine copper(II) sulfate is shipped out for further refining to Eastern Canada.

3. Write the equation for the precipitation of nickel metal. (Equation 13.)

4. About 45 t of nickel is produced each day. How many moles of hydrogen would be required to produce this amount of nickel? (Equation 13.)

FERTILIZERS

Introduction

Fertilizers are an important aspect of modern agriculture. Western Canada, with its large agricultural base, represents a large market for fertilizers. Manufacturing of fertilizers is an important part of Alberta's economy because fertilizer plants require large supplies of natural gas as well as because of the market.

The purpose of a fertilizer is to replace depleted or nonexistent plant nutrients in soils. Plant nutrients are those elements essential to plant growth.

Table S2

Essential Elements to Plant Growth

nitrogen	calcium	copper	zinc	chlorine
phosphorus	magnesium	boron	iron	
potassium	sulfur	manganese	molybdenum	

Most soils contain sufficient amounts of these essential elements for natural plant growth. Farmers however, remove the natural growth and replace it with plants which are marketable. These plants may require different amounts of essential elements than those found in the soil and/or may deplete the minerals in the soil. The elements nitrogen, phosphorus and potassium are most essential and are the elements most often missing or depleted from the soil. Commercial fertilizers contain at least one of the elements nitrogen, phosphorus and potassium.

History

100 years ago only natural materials, manure, compost (a mixture of decayed plant materials, leaves, stems and roots) and peat mosses were thought to be capable of fertilizing soils. These natural materials were spread on the soil by farmers.

About 100 years ago, Justis von Liebig, a German scientist, set out to show that any materials which replaced the essential elements would act as a fertilizer and improve plant growth. Using a small plot of land, von Liebig added chemicals containing the essential elements. Thus began the fertilizer revolution. Today chemical fertilizers are used around the world. Food production has risen dramatically wherever fertilizers have been applied.

Fertilizer Rating

Fertilizers sold in Canada are marked with a set of three numbers. These three numbers indicate the percentages of nitrogen, phophorus and potassium found in the fertilizer. (16-20-0) fertilizer means 16% nitrogen, 20% phophorus as P_2O_5 and 0% potassium as K_2O.

The percentage of phosphorus and potassium are done as P_2O_5 and K_2O because historically geologists indicated rock and ore element components as oxides even if the oxides were not present. Fertilizers do not contain P_2O_5 or K_2O. Compounds of phosphorus and potassium other than oxides are used in fertilizers. Canada is one of few countries which still uses the P_2O_5 and K_2O system. All other elements (such as sulfur and iron) are indicated as a direct percent of the elements (like nitrogen).

Blended Ferilizers

Fertilizers are often bagged and sold as individual compounds or they may be mixed or *blended* to give different percentages of essential nutrients. Some fertilizers are *blended* using several compounds and so contain 4 or 5 of the elements needed by the soil. A fertilizer which contains nitrogen, phosphorus, potassium and a couple of other elements is sometimes called a *complete* fertilizer because it contains all of the elements any soil should need.

The best fertilizer is the one which supplies the elements needed by that soil. On the prairies few soils require potassium. As a result less than 5% of fertilizer sales on the prairies is accounted for by potash fertilizers. Potash for fertilizers is mined in Saskatchewan.

Fertilizers containing sulfur make up to 15% of sales on the prairies. The sulfur for these fertilizers is extracted from Alberta natural gas.

ALBERTA CHEMICAL INDUSTRIES
FERTILIZERS

1. State two reasons why fertilizer plants are located in Alberta.

2. What is the purpose of a fertilizer?

3. What are the three essential elements contained in most fertilizers?

4. Name three natural fertilizers.

5. 11-48-0 is a fertilizer commonly used in Canada. What do the three numbers indicate?

ALBERTA CHEMICAL INDUSTRIES

FERTILIZERS

The location and products of several Alberta fertilizer plants are shown in the table below.

Table S3

Alberta Fertilizer Plants

Company	Location	Fertilizers
Sherritt Gordon Mines Ltd.	Fort Saskatchewan	ammonium sulfate ammonium phosphates ammonia urea ($(NH_2)_2CO$) urea sulfate
Western Co-operative Fertilizers	Calgary Medicine Hat	ammonia ammonium nitrate ammonium nitrate, phosphate ammonium nitrate, sulfate ammonium phosphates ammonium phosphate, sulfate
Cominco Ltd.	Calgary Carseland	ammonia ammonium nitrate nitrogen solutions urea
Esso Chemical Canada	Redwater	ammonia ammonium nitrate ammonium nitrate phosphate ammonium phosphates ammonium phosphate, sulfate
Canadian Fertilizer Limited*	Medicine Hat	ammonia urea

* New plant - owned by Western Co-operative Fertilizers, CF Industries, Co-operative Federee de Quebec and United Co-operatives of Ontario.

1. Write chemical formulas for the fertilizers which contain single compounds.

2. *Ammonium phosphates* in fertilizers are ammonium dihydrogen phosphate and ammonium monohydrogen phosphate. Write the formulas for the *ammonium phosphates*.

3. *Ammonia nitrate, phosphate* written on a fertilizer bag means a *blend* of ammonium nitrate and ammonium phosphates. Write the formulas for the compounds found in fertilizers with the other names listed in the chart on Page S9 - (Urea sulfate is a blended fertilizer as well.)

4. Which of the three essential nutrients found in most fertilizers is not produced in Alberta? Give one reason which may account for this element not being produced.

ALBERTA CHEMICAL INDUSTRIES

THE TWO FACES OF NITROGEN

Nitrogen may react to produce pollutants (Los Angeles-type smog - which sometimes occurs in Calgary and Edmonton) or nitrogen may react to produce beneficial nitrogen fertilizers.

Los Angeles-type smog results from a combination of nitrogen oxides, ozone, and hundreds of ozonated hydrocarbons being trapped in a thermal inversion with the sun shining.

____ 1. Nitrogen and oxygen gas react in the combustion cylinder of a car (or as a result of lightning in the air) to produce nitrogen monoxide.

____ 2. Almost immediately the nitrogen monoxide reacts with oxygen to product nitrogen dioxide (a brown-orange toxic gas which helps give the dark color to LA smog).

____ 3. Sunlight causes the nitrogen dioxide to decompose into nitrogen monoxide and atomic oxygen (monoxygen).

____ 4. Atomic oxygen reacts quickly with molecular oxygen to produce the toxic and corrosive pollutant ozone (O_3).

____ 5. Some ozone reacts with nitrogen monoxide to produce nitrogen dioxide and oxygen.

The other face of nitrogen involves nature's nitrogen cycle and man's duplication or alternatives to it.

____ 6. In nature Reactions 1 and 2 occur as a result of lightning. The nitrogen dioxide is then literally rained to the ground as nitric acid (i.e., nitrogen dioxide reacts with rain and oxygen).

____ 7. Nitric acid is produced in Alberta fertilizer plants by reacting ammonia with oxygen to produce nitric acid and water.

____ 8. Rhizobia bacteria in plant roots remove nitrogen from the air to combine with hydrogen (assume atomic hydrogen from organic compounds) to form ammonia.

____ 9. Fertilizer plants in Alberta produce ammonia by reacting nitrogen (from the air) with hydrogen (from decomposed natural gas) at high temperatures and pressures.

____ 10. A combination ammonium and nitrate fertilizer is produced by man by reacting ammonia with nitric acid to produce ammonium nitrate (33-0-0 fertilizer).

ALBERTA CHEMICAL INDUSTRIES

FERTILIZERS

Page S5 contains a flow chart which shows the main chemical reactions involved in the production of fertilizers. The first step in this production is the synthesis of ammonia, which has already been described under the Sherritt Gordon nickel refining process.

1. Using the word equation under *Urea Production* write the balanced chemical equation for the reaction to produce urea. The formula for urea is $(NH_2)_2CO$).(Equation 4.)

2. 1200 t of urea is produced each day at Carseland by Cominco Ltd. Determine the number of moles of ammonia required for this reaction.

3. Esso Chemical Canada produces nitric acid as shown in the chart under *Nitric Acid Production*. Write balanced chemical equations for the reactions described in the word equations for the production of nitric acid.

4. How many moles of ammonia would be required to produce 3 300 mol of nitrogen monoxide?

5. The nitric acid produced by Esso Chemicals is used to produce ammonium nitrate fertilizer. Write the balanced chemical equation for the reaction.

6. Western Co-operative Fertilizers produce sulfuric acid as shown in the chart under *Sulfuric Acid Production* in both Calgary and Medicine Hat. Write balanced chemical equations for the reactions in the production of sulfuric acid.

ALBERTA CHEMICALS INDUSTRIES

FERTILIZERS

7. What mass of sulfur would be required to produce 15.6 kmol of sulfur dioxide?

8. Sherritt Gordon Mines Limited uses sulfuric acid produced by a similar reaction to react with calcium phosphate rock from Florida. 135 t of phosphoric acid in solution is produced each day. Determine the mass of calcium phosphate used each day.

9. The phosphoric acid is used to produce phosphate fertilizer. Write the balanced chemical equations for these two reactions.

10. What chemical substance produced during the reactions represented in the flow chart are not used by the fertilizer plants in their fertilizer process?

11. List chemicals which the fertilizer plants market.

12. Western Co-op Fertilizers used 390 t/d of sulfur for their Calgary plant. How many moles of sulfur trioxide would they produce each day?

Problems Associated With the Use of Fertilizers

Fertilizing agricultural land eventually leads to fertilization of surrounding areas. The nitrates and phosphates, being soluble in water, are washed away to collect in lakes and rivers. In these waters they promote the growth of algae and other plants. These plants collect on the surface of the water and prevent sunlight from penetrating down to underwater plants. Less oxygen is produced at these lower levels. The result is that animal life in the lake dies from lack of oxygen. Some environmentalists call this the *death of a lake.*

Nitrates in water can also cause more direct problems to humans. Removing nitrates from drinking water is very difficult. Infants drinking water containing nitrates can get a blood disease called methemoglobinemia, which can kill. Adults can tolerate a much higher amount of nitrate before they become ill.

Another problem with fertilizers is cost. The production of nitrate and phosphate fertilizers requires energy. The energy crisis has resulted in the cost of fuels becoming prohibitive for many consuming developing nations. These nations are the very ones whose food production needs to be raised significantly.

The solution to the problem maylie in a better understanding of the nitrogen cycle.

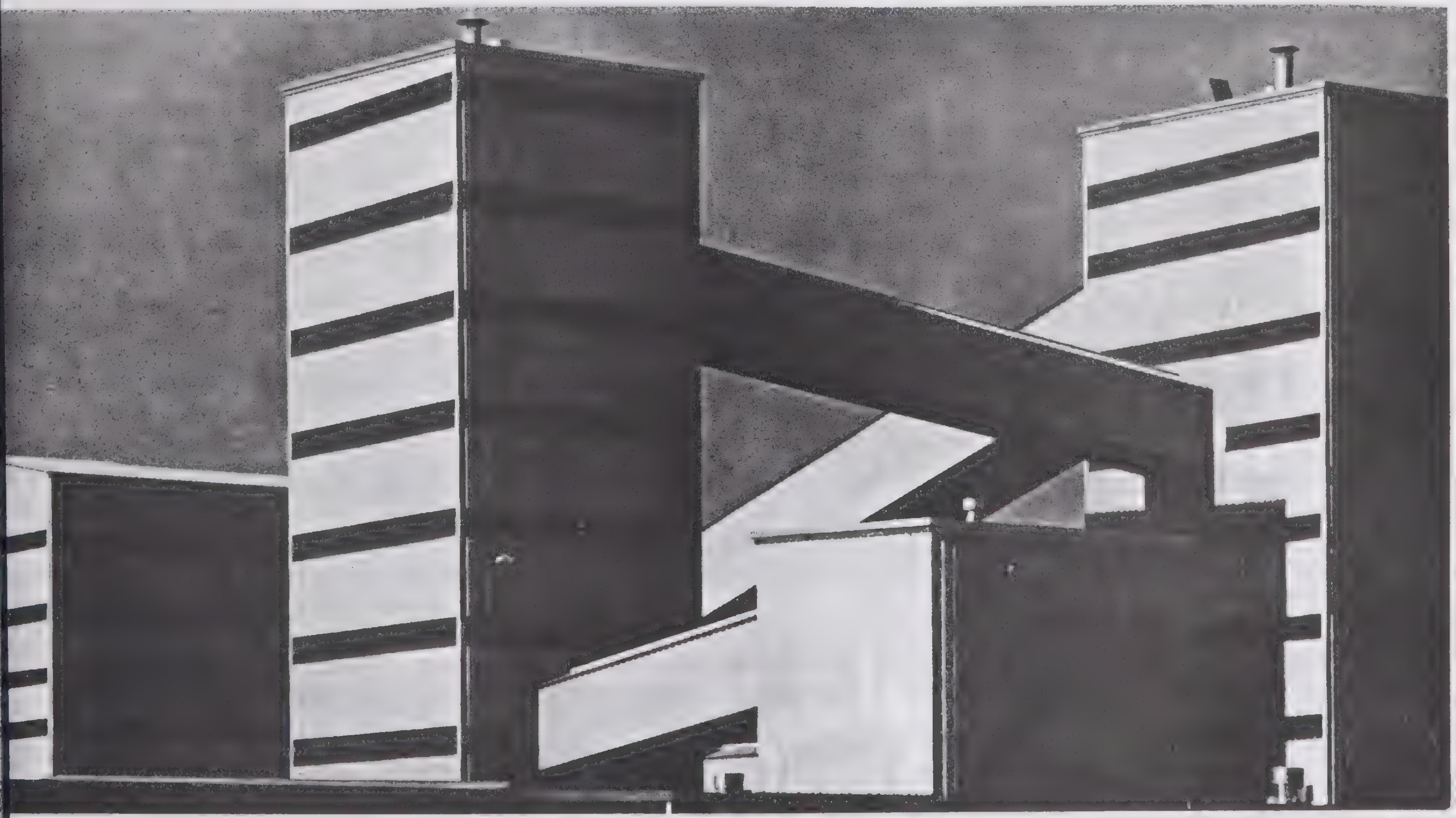


Figure S3

Esso Imperial's Redwater Blending Plant

ALBERTA CHEMICAL INDUSTRIES

STEEL BROTHERS CANADA LTD.

Exshaw, Alberta, near the entrance to Banff National Park on the Trans Canada highway, is the site of Steel Brothers Canada Ltd. plant for the production of lime. The limestone for the plant is mined eight miles west of the plant in the Rundle Mountain formation. This limestone has a high calcium content. The lime plant, which has a capacity of 410 t/d, changes the limestone into calcium oxide.

Write balanced chemical equations for the word equations below:

1. Limestone (calcium carbonate) is heated in huge rotating kilns to 1500°C. The limestone decomposes into lime (calcium oxide) and carbon dioxide. Some of this is bagged and sold directly as lime.

2. Some of the lime is reacted with warm water to make slaked lime (calcium hydroxide).

3. What is the mass of calcium carbonate required to produce 410 t/d of calcium oxide?

4. Assume 150 t/d of the calcium oxide is slaked. What mass of slaked lime would be produced?

Lime is second in tonnage only to sulphuric acid as an important industrial chemical. It's uses are many and varied. Only a few uses, important in Alberta will be stressed.

ALBERTA CHEMICAL INDUSTRIES

CANADIAN LIQUID AIR

Canadian Liquid Air produces many gases and markets them in cylinders under high pressure.

Table S4

Some *Canadian Liquid Air* Products

Gas	Where Bottled	Source
acetylene	Edmonton	Chemical reaction with Calcium carbide
hydrogen	Edmonton	Electrolysis of Water
nitrogen	Edmonton	Fractional Distillation of liquid air
oxygen	Edmonton	Fractional Distillation of liquid air
carbon dioxide	Lethbridge	Western Co-operative Fertilizers Medicine Hat Ammonia Plant
argon	Vancouver, B.C.	Fractional Distillation of liquid air
helium	Swift Current, Sask.	Natural gas wells in Saskatchewan with high helium content
nitrous oxides	Vancouver, B.C.	

The Edmonton plant on Stadium Road produces 200 cylinders (1.5 t) of oxygen each day as well as nitrogen by the *fractional distillation* of air.

Distillation

Every chemical substance has a melting point and a boiling point which is characteristic for that substance. The boiling points for the elements are given on the ALCHEM *Periodic Table of the Elements*.

Distillation is a physical process which makes use of the fact that each substance has a boiling point which is unique to that substance. A chamber is set up and the substance required is heated to its boiling point. At that temperature all of that substance boils and no other. If the gas formed is cooled and collected the result is a pure substance. Pure water can be produced from sea water by distillation.

Fractional Distillation

Sometimes a chemical process produces several chemicals which need to be prepared for sale or for use as raw materials for other reactions. First all of the substances are liquified and are placed in a chamber, which is usually a large cylinder. The liquids are then boiled off. The temperature in the column is selectively controlled so that at some particular height one of the substances will liquify. This will be the substance with the highest boiling point.

CANADIAN LIQUID AIR

Some device at that height traps the liquid which is then drawn off. As the remaining gases move up the column, the next highest boiling point will be reached and that liquid will be drawn off. This process is called *fractional distillation.*

Canadian Liquid air liquifies air which contains nitrogen gas, oxygen gas and other gases, mainly argon. This liquid air is then allowed to warm until -196°C. At this temperature the nitrogen is boiled off and collected. The air is then warmed to -186°C (Vancouver only) and argon is collected. The only gas remaining will be liquid oxygen which can be collected last by boiling. Any other gas will boil off at lower temperatures or will still remain after the oxygen has been removed.

Consecutive Distillations

If a very pure substance is required the distillation process is repeated with the purer substance in a second chamber until the required purity has been achieved.

Most chemical industries use fractional distillation or distillation in the purification of their products.

1. At what temperature would the oxygen boil off?

2. At what temperature would any neon or Krypton boil off?

3. Write the order in which the gases would be collected if air was to be separated into N_2,O_2, Ar, Ne, Kr and Xe.

The chemist, however is more interested in the production of acetylene and hydrogen gas as these are produced by chemical reactions.

Acetylene

Acetylene was discovered by Edmond Davy in 1836. It remained unknown as a practical source of heat until 1892 when it was discovered that calcium carbide could be produced by the reaction of lime with coke. Once actylene was being produced it had to be stored. This created a problem because whenever acetylene is pressured above 186 kPa (standard atmospheric pressure is 101 kPa), it acquires explosive properties. For some time transportation and use of acetylene was prohibited.

Acetylene gas dissolves very well in liquid acetone. As acetylene gas pressure increases the solubility of acetylene in liquid acetone increases and the explosive property is not a problem. Because of this acetylene may now be transported and sold anywhere.

Acetylene Production

1. Acetylene gas is produced when calcium carbide reacts with water. The other product is calcium hydroxide. Write the balanced chemical equation.

ALBERTA CHEMICAL INDUSTRIES

CANADIAN LIQUID AIR

2. The acetylene produced is then introduced into an acetone charged cylinder at a pressure of 103 kPa. (This is only 2 kPa above standard atmospheric pressure.) This dissolving process may take several hours. Once the acetylene is dissolved and stored it can be used at any time as a fuel. Write the balanced equation for the combustion of acetylene ($C_2H_{2(g)}$) in pure oxygen. This reaction produces the hottest chemical flame known.

The electrolysis of water is done in ALCHEM 10 Lab C3 using a Hoffman's Apparatus. Canadian Liquid Air uses a much larger set up to produce hydrogen gas commercially but the reaction is the same.

1. Write a balanced chemical equation for the electrolytic decomposition of water.

2. 0.4298 kg of hydrogen gas (5 405 L at 20°C and 101 kPa) are produced each day. What mass of water must be decomposed to produce this much hydrogen gas?

3. What would be the number of kilomoles of acetylene produced when 2.0 t of calcium carbide, $CaC_{2(s)}$, reacts completely with sufficient water?

$$\_\_CaC_{2(s)} + \_\_H_2O_{(\ell)} \longrightarrow \_\_C_2H_{2(g)} + \_\_Ca(OH)_{2(s)}$$

ALBERTA CHEMICAL INDUSTRIES

THIO-PET CHEMICALS LTD.

Thio-Pet Chemicals Ltd. in Fort Saskatchewan reacts sulfur with methane from natural gas to produce carbon disulfide and hydrogen sulfide.

1. Write the balanced chemical equation for methane and sulfur reaction.

The hydrogen sulfide and carbon disulfide products are separated by distillation. Both are further purified by distillation until they are 99%+ pure. Sherritt Gordon uses about 2270 kg/d of hydrogen sulfide . . . while the remainder is sent to heavy water plants in Glace Bay and Port Hawkesbury in Nova Scotia, and to Douglas Point in Ontario for Ontario Hydro (9070 kg/d). The carbon disulfide is used to wash oil wells, to produce xanthates by CIL and remainder sold to Dow Chemical in California.

2. Determine the mass of carbon disulfide produced in a day at the Thio-Pet carbon disulfide, hydrogen sulfide plant.

3. How many moles of methane would be used each day to produce 11 340 kg/d of hydrogen sulfide?

4. If each mole of methane occupies about 25 L, under normal room conditions what volume of methane would be used?

ALBERTA CHEMICAL INDUSTRIES
ALBERTA GAS CHEMICALS

Alberta Gas Chemicals in Medicine Hat produces methanol by a reaction of methane with steam to produce both oxides of carbon and hydrogen gas.

1. Write the balanced chemical equation.

2. Both carbon oxides react with hydrogen in the same equation to produce methanol. Write the balanced chemical equation.

3. What mass of water would be used for every 100 mol of methane which reacts?

The methanol produced is purified by a series of three distillations until it is 99.85% pure. It is then shipped to Celanese Canada's Edmonton plant.

4. Give some reasons why the plant is located in Medicine Hat.

5. How many moles of carbon monoxide would be required to react with 2 000 mol of hydrogen gas?

ALBERTA CHEMICAL INDUSTRIES
ALBERTA SULPHATE, MOUNTAIN MINERALS

Alberta Sulphate uses an unusual mining method to produce Glaubers salt (sodium sulfate decahydrate). Hot water is pumped into the deposit near Mestiskow, Alberta dissolving the salts which is then piped into cooling vats in the plant. The salts crystallize, the water is available for recycling and the process continues. A 99.56% pure sodium sulfate is produced after heating.

1. Write the formula for glaubers salt.

2. Write the formula for the product if glaubers salt is heated.

3. What mass of sodium sulfate decahydrate would have to be heated to produce 1.0 t of dry sodium sulfate?

4. Mountain Minerals in Lethbridge mines barite (barium sulfate). Barite is the worlds main source of barium compounds. Before the reactions can be carried out barium sulfate is reacted with sodium carbonate to produce barium carbonate which is soluble in acids. Write the balanced chemical equation for the reaction.

5. What mass of barite would be required to produce 1.00 t of barium carbonate?

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